UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to:
OSB2001-0155-FEC

November 6, 2001

Mr. Lawrence C. Evans
U.S. Army Corps of Engineers
Attn: Judy Linton
Regulatory Branch, CENWP-OP-G
P.O. Box 2946
Portland, OR 97208-2946

Re: Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Act Essential Fish Habitat Consultation for Maintenance Dredging by Port of Portland at Terminal 2 and Terminal 5, Willamette River, Multnomah County, Oregon (Corps No. 2001-00688 and 2001-00689)

Dear Mr. Evans:

Enclosed is a biological opinion (Opinion) prepared by the National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act (ESA) on the effects of proposed maintenance dredging by the Port of Portland at Terminal 2 and Terminal 5, Willamette River, Multnomah County, Oregon. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of ESA-listed Snake River sockeye salmon (*Oncorhynchus nerka*), Snake River fall chinook salmon (*O. tshawytscha*), Snake River spring/summer chinook salmon, Upper Columbia River spring-run chinook salmon, Lower Columbia River chinook salmon, Upper Willamette River chinook salmon, Columbia River chum salmon (*O. keta*), Snake River steelhead (*O. mykiss*), Upper Columbia River steelhead, Middle Columbia River steelhead, Upper Willamette River steelhead, and Lower Columbia River steelhead, or destroy or adversely modify designated critical habitat(s). As required by section 7 of the ESA, NMFS included reasonable and prudent measures with non-discretionary terms and conditions that NMFS believes are necessary to minimize the impact of incidental take associated with this action.

This Opinion also serves as consultation on Essential Fish Habitat pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act and implementing regulations at 50 CFR Part 600.

If you have any questions regarding this consultation, please contact Christy Fellas of my staff in the Oregon Habitat Branch at 503.231.2307.

Sincerely,

for Michael R Crouse

D. Robert Lohn
Regional Administrator

Endangered Species Act - Section 7 Consultation
&
Magnuson-Stevens Act Essential Fish Habitat Consultation

BIOLOGICAL OPINION

Maintenance Dredging by Port of Portland
at Terminal 2 and Terminal 5,
Willamette River, Multnomah County, Oregon
(Corps No. 2001-00688 and 2001-00689)

Agency: Army Corps of Engineers, Portland District

Consultation Conducted By: National Marine Fisheries Service, Northwest Region

Date Issued: November 6, 2001

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1. ENDANGERED SPECIES ACT

1.1 Background

On October 10, 2001 the National Marine Fisheries Service (NMFS) received a letter from the Corps of Engineers (COE) requesting formal consultation on the issuance of a 5 year maintenance dredging permit to the Port of Portland for dredging in the Willamette River. The proposed action is the dredging of Terminal 2 (T-2) and Terminal 5 (T-5). In the October 10, 2001 letter, the COE determined that Snake River sockeye salmon (*Oncorhynchus nerka*), Snake River spring/summer chinook salmon (*O. tshawytscha*), Snake River fall chinook salmon (*O. tshawytscha*), Lower Columbia River steelhead (*O. mykiss*), Upper Columbia River steelhead (*O. mykiss*), Snake River steelhead (*O. mykiss*), Middle Columbia River steelhead (*O. mykiss*), Columbia River chum salmon (*O. keta*), Lower Columbia River chinook salmon (*O. tshawytscha*), Upper Columbia River spring run chinook salmon (*O. tshawytscha*), Upper Willamette River steelhead (*O. mykiss*) and Upper Willamette River chinook (*O. tshawytscha*) may occur within the project area and that the proposed project is "likely to adversely affect" (LAA) the subject listed species or their designated critical habitat. References and dates listing status, critical habitat designations and ESA section 4(d) take prohibitions are listed in Table 1.

The NMFS has prepared this biological opinion (Opinion) to address impacts to these species as a result of the proposed project. The objective of this Opinion is to determine whether the action to dredge around the two docks in the Willamette River is likely to jeopardize the continued existence of the above listed species or destroy or adversely modify critical habitat.

1.2 Proposed Action

Terminal 2
The proposed action at Terminal 2 (T-2) is the maintenance dredging of berthing facilities located in the lower Willamette River. The purpose of dredging is to maintain authorized navigational depths of -20 feet Columbia River Datum (CRD) at Berth 203 and -40 feet CRD at Berths 204-206. These facilities function as one of the Port of Portland's main water-dependent cargo transportation access points for deep-draft vessels. The proposed dredging will occur within the 8.7 acres of berthing space at T-2. Estimated dredging frequency is no more than annually, with dredged material volume per episode not to exceed 25,000 cubic yards. The proposed project area for T-2 is located ½ mile upstream of the current geographical limit of the Portland Harbor Superfund site.

Terminal 5
The proposed action at Terminal 5 (T-5) is the maintenance dredging of berthing facilities located in the lower Willamette River. The purpose of dredging is to maintain authorized navigational depths of -40 feet CRD at Berths 501 and 503 and -35 feet CRD at Berth 502. These facilities function as one of the Port of Portland's main water-dependent cargo transportation access points for deep-draft vessels. The proposed dredging will occur within the 13.5 acres of berthing space at T-5. Estimated dredging frequency is annually, with dredged

material volume per episode not to exceed 8,000 cubic yards. The proposed project area for T-5 is located 1.5 miles downstream of the current geographical limit of the Portland Harbor Superfund site.

Dredging will include an allowable two-feet of over depth as advanced maintenance of expected sediment infill. All material at both terminals will be removed using a clamshell dredge and transported in haul barges. The clamshell bucket is operated from a floating crane and is designed to reduce sediment resuspension by forming a seal when the bucket is closed and retrieved to the surface. If necessary, the rate of clamshell dredging will be reduced so that the plume of sediments generated by an individual grab has time to be diluted prior to the next grab. The need for modification to the rate of dredging will be based on a turbidity monitoring program conducted with each dredging event. Sediments are placed in a flatbed barge with sideboards or a bin barge with one or multiple cells. The process of clamshell dredging has an accuracy of 1 to 2 feet and a post-dredge survey will be performed to verify navigational depths have been restored in all berthing areas.

All material will be disposed of upland, at the Port's Suttle Road dredge material rehandle facility located east and upstream of Terminal 6 on the Columbia River. The rehandle facility consists of two cells, one to hold the dredge material and one to hold the decanted water. A Column Settling Test (CST) will be conducted for material from each dredge prism prior to discharge to ensure that the turbidity levels meet Oregon Water Quality Certification criteria. This test will be used to establish holding time needed before water from the holding basin can be allowed to discharge to the river. This return water is proposed for discharge to the Columbia River in accordance with state water quality certification requirements.

The Port will continue to conduct bathymetric surveys of T-2 and T-5 to assess the condition of the available navigational depths. These surveys are used to identify the specific locations where Columbia and Willamette Rivers sediments have accumulated above authorized navigational depth. The sediment characterization report for this dredging project states that sediments from the proposed dredge prism are suitable for unconfined, open-water disposal since all detected potential chemicals were below corresponding screening criteria. The only exception is berth 203 which did not meet screening criteria and will not be dredged this year. The Port will conduct sediment analyses at berths prior to each dredging episode to test for presence of contaminants. Water from the rehandle facility will be held based on the CST before discharge to the river.

1.3 Biological Information and Critical Habitat

The action area is defined by NMFS regulations (50 CFR 402) as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The action area includes designated critical habitat affected by the proposed action within the Willlamette River. The action area for the proposed project includes: 1) The actual dredging area (within 13.5 acres) and Willamette River downstream to its confluence with Columbia River for T-5; 2) the actual dredging area (within 8.7 acres) and Willamette River downstream for 1000 feet for T-2; and 3) the discharge point to approximately 500 feet downstream in the Columbia River for the rehandle facility.

The Willamette and Columbia Rivers at Portland, Oregon serve as migration areas for all listed species under consideration in this Opinion. They may also serve as feeding and rearing areas for juvenile chum and sub-yearling chinook salmon. Essential features of the action area for the listed species are: (1) Substrate; (2) water quality; (3) water quantity; (4) water temperature; (5) water velocity; (6) cover/shelter; (7) food (juvenile only); (8) riparian vegetation; (9) space; and (10) safe passage conditions (50 CFR 226). The essential features this proposed project may affect are water quality (turbidity and contaminants) and disturbance of river substrate resulting from the dredging activities.

1.4 Evaluating Proposed Actions

The standards for determining jeopardy are set forth in section 7(a)(2) of the ESA as defined by 50 CFR Part 402 (the consultation regulations). NMFS must determine whether the action is likely to jeopardize the listed species and/or whether the action is likely to destroy or adversely modify designated critical habitat. This analysis involves the initial steps of (1) Defining the biological requirements and current status of the listed species, and (2) evaluating the relevance of the environmental baseline to the species' current status.

Subsequently, NMFS evaluates whether the action is likely to jeopardize the listed species by determining if the species can be expected to survive with an adequate potential for recovery. In making this determination, NMFS must consider the estimated level of mortality attributable to: (1) Collective effects of the proposed or continuing action, (2) the environmental baseline, and (3) any cumulative effects. If NMFS finds that the action is likely to jeopardize the listed species, NMFS must identify reasonable and prudent alternatives for the action.

Furthermore, NMFS evaluates whether the action, directly or indirectly, is likely to destroy or adversely modify the listed species' designated critical habitat. NMFS must determine whether habitat modifications appreciably diminish the value of critical habitat for both survival and recovery of the listed species. NMFS identifies those effects of the action that impair the function of any essential element of critical habitat. If NMFS concludes that the action will destroy or adversely modify critical habitat, it must identify any reasonable and prudent measures available.

For the proposed action, a jeopardy analysis by NMFS considers direct or indirect mortality of fish attributable to the action. A critical habitat analysis by NMFS considers the extent to which the proposed action impairs the function of essential elements necessary for migration, spawning, and rearing salmon under the existing environmental baseline.

Table 1. References for additional background on listing status, biological information, and critical habitat elements for the listed and proposed species addressed in this biological opinion.

Species	Listing Status	Critical Habitat	Protective Regulations	Biological Information, Historical Population Trends
Columbia River chum salmon	March 25, 1999; 64 FR 14508, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Johnson *et al.* 1997; Salo 1991
Lower Columbia River steelhead	March 19, 1998; 63 FR 13347, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Middle Columbia River steelhead	March 25, 1999; 64 FR 14517, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Upper Columbia River steelhead	August 18, 1997; 62 FR 43937, Endangered	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Upper Willamette River steelhead	March 25, 1999 64 FR 14517, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Snake River Basin steelhead	August 18, 1997; 62 FR 43937, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Snake River sockeye salmon	November 20, 1991; 56 FR 58619, Endangered	December 28, 1993; 58 FR 68543	November 20, 1991; 56 FR 58619	Waples *et al.* 1991a; Burgner 1991
Lower Columbia River chinook salmon	March 24, 1999; 64 FR 14308, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Myers *et al.*1998; Healey 1991
Upper Columbia River spring-run chinook salmon	March 24, 1999; 64 FR 14308, Endangered	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Myers *et al.*1998; Healey 1991
Upper Willamette River chinook salmon	March 24, 1999; 64 FR 14308, Threatened	February 16, 2000; 65 FR 7764	July 10, 2000; 65 FR 42422	Busby *et al.* 1995; 1996
Snake River spring/summer-run chinook salmon	April 22, 1992; 57 FR 14653, Threatened	December 28, 1993; 58 FR 68543	April 22, 1992; 57 FR 14653	Matthews and Waples 1991; Healey 1991
Snake River fall chinook salmon	April 22, 1992; 57 FR 14653, Threatened	December 28, 1993; 58 FR 68543	April 22, 1992; 57 FR 14653	Waples *et al.* 1991b; Healey 1991

1.4.1 Biological Requirements

The first step in the methods NMFS uses for applying the ESA section 7(a)(2) to listed salmonids is to define the species' biological requirements that are most relevant to each consultation. The NMFS also considers the current status of the listed species taking into account population size, trends, distribution and genetic diversity. To assess to the current status of the listed species, NMFS starts with the determinations made in its decision to list the species for ESA protection and also considers new data available that is relevant to the determination.

The relevant biological requirements are those necessary for the listed species to survive and recover to a naturally reproducing population level at which protection under the ESA would become unnecessary. Adequate population levels must safeguard the genetic diversity of the listed stock, enhance its capacity to adapt to various environmental conditions, and allow it to become self-sustaining in the natural environment.

For this consultation, the biological requirements are improved habitat characteristics that function to support successful rearing and migration. The current status of the listed species, based upon their risk of extinction, has not significantly improved since the species were listed.

1.4.2 Environmental Baseline

The Willamette watershed covers a vast area (11,500 square miles) bordered on the east and west by the Cascades and the Pacific coast ranges. It drains from as far south as Cottage Grove and flows north to its confluence with the Columbia River. The Willamette River watershed is the largest river basin in Oregon. It is home to most of the state's population, its largest cities, and many major industries. The watershed also contains some of Oregon's most productive agricultural lands and supports important fishery resources (City of Portland 2001).

The uplands (Coast and Cascade ranges) receive about 80 percent of the precipitation falling on the Willamette River Basin, and store much of this water as snow. Ecosystem productivity in these upland streams is relatively low, with aquatic insects gleaning much of their diet from material that falls into running water. In larger, slower tributaries, more plant material is produced in the stream itself. The mainstem supports a highly productive algal community that blooms as temperatures rise in the summer. Insects and some vertebrates feed on these plants, and many vertebrates, including salmonids, feed on stream-dwelling insects. Much of the habitat for Willamette River salmonids has been degraded by various land use practices or eliminated by dams. Wild salmonid populations have declined precipitously over the last century in the Willamette River (WRI 1999).

Basin health has been affected in terms of water and habitat quality and quantity. Many native species have been adversely affected due to the introduction of non-native species, loss of habitat and habitat degradation, and contaminated waters which impede species' development (WRI 1999). Some streams and rivers in the basin have high temperatures and insufficient flows during summer months, which adversely impact aquatic species such as salmon and steelhead

(WRI 1999). The Willamette River from the mouth to Willamette Falls is currently listed on the 1998 Oregon Department of Environmental Quality (DEQ) 303(d) list for the following parameters: Temperature, bacteria, biological criteria and toxics. Increased population and development have further compounded these problems, resulting in the loss of much critical habitat and increased pollution (WRI 1999).

The most recent evaluation of the environmental baseline for the Columbia River is part of the NMFS's Opinion for the Federal Columbia River Power System (FCRPS) issued in December 2000. That baseline is summarized here. For a detailed evaluation of the Columbia River basin, please refer to the FCRPS Opinion (NMFS 2000).

The quality and quantity of freshwater habitat in much of the Columbia River basin have declined dramatically in the last 150 years. Forestry, farming, grazing, road construction, hydrosystem development, mining, and urbanization have radically changed the historical habitat conditions of the basin. With the exception of fall chinook, which generally spawn and rear in the mainstem, salmon and steelhead spawning and rearing habitat is found in tributaries to the Columbia and Snake rivers. Anadromous fish typically spend from a few months to 3 years rearing in freshwater tributaries. Depending on the species, they spend from a few days to 1 or 2 years in the Columbia River estuary before migrating out to the ocean and another 1 to 4 years in the ocean before returning as adults to spawn in their natal streams. Thirty-two subbasins provide spawning and rearing habitat.

Water quality in streams throughout the Columbia River basin has been degraded by human activities such as dams and diversion structures, water withdrawals, farming and grazing, road construction, timber harvest activities, mining activities, and urbanization. Over 2,500 streams and river segments and lakes do not meet Federally approved, state and Tribal water quality standards and are now listed as water-quality-limited under Section 303(d) of the CWA. Tributary water quality problems contribute to poor water quality where sediment and contaminants from the tributaries settle in mainstem reaches and the estuary.

Water quantity problems are also a significant cause of habitat degradation and reduced fish production. Withdrawing water for irrigation, urban, and other uses can increase temperatures, smolt travel time, and sedimentation. Return water from irrigated fields can introduce nutrients and pesticides into streams and rivers. On a larger landscape scale, human activities have affected the timing and amount of peak water runoff from rain and snowmelt. Many riparian areas, flood plains, and wetlands that once stored water during periods of high runoff have been developed. Urbanization paves over or compacts soil and increases the amount and pattern of runoff reaching rivers and streams.

The environmental baseline has been degraded by urbanization, industrialization and human activity in the Columbia and Willamette Rivers. The action area for the proposed project contains marinas and docks as well as a large area of industrial shipping facilities. The riparian area contains little or no cover and vegetation in these stretches of the river. The urbanization of this area contributes to the degraded conditions of the Columbia and Willamette Rivers including

reduced water quality, increased water temperature, altered timing and quantity of runoff and decrease in riparian cover and habitat refugia.

1.5 Analysis of Effects

1.5.1 Effects of Proposed Action

Dredging and disposal of the dredged material speed up the natural processes of sediment erosion, transportation and deposition (Morton 1977). The physical effects to the river system from dredging and disposal briefly summarized are: Temporary increases in turbidity, changes in bottom topography with resultant changes in water circulation, and changes in the mechanical properties of the sediment at the dredge and disposal sites (Morton 1977). The significance of the effect is a function of the ratio of the size of the dredged area to the size of the bottom area and water volume (Morton 1977).

Potential impacts to listed salmonids from the proposed action include both direct and indirect effects. Potential direct effects include entrainment of juvenile fish (Dutta and Sookachoff 1975a, Boyd 1975, Armstrong *et al.* 1982, Tutty 1976) and mortality from exposure to suspended sediments (turbidity). Potential indirect effects include behavioral (Sigler *et al.* 1984, Berg and Northcote 1985, Whitman et al. 1982, Gregory 1988) and sub-lethal impacts from exposure to increased turbidity (Sigler 1988, Sigler *et al.* 1984, Kirn *et al.* 1986, Emmett *et al.* 1988, Servizi 1988); mortality from predatory species that benefit from activities associated with dredged material disposal; and loss of benthic food sources resulting from dredging and disposal of dredged material (Morton 1977).

Suspended sediment and turbidity influences on fish reported in the literature range from beneficial to detrimental. Elevated total suspended solids (TSS) conditions have been reported to enhance cover conditions, reduce piscivorous fish/bird predation rates, and improve survival. Elevated TSS conditions have also been reported to cause physiological stress, reduce growth, and adversely affect survival. Of key importance in considering the detrimental effects of TSS on fish are the frequency and the duration of the exposure (not just the TSS concentration).

Behavioral avoidance of turbid waters may be one of the most important effects of suspended sediments (DeVore *et al.* 1980, Birtwell *et al.* 1984, Scannell 1988). Salmonids have been observed to move laterally and downstream to avoid turbid plumes (McLeay *et al.* 1984, 1987, Sigler *et al.* 1984, Lloyd 1987, Scannell 1988, Servizi and Martens 1991). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities, except when the fish need to traverse these streams along migration routes (Lloyd *et al.* 1987). In addition, a potentially positive reported effect is providing refuge and cover from predation (Gregory and Levings 1988).

Fish that remain in turbid, or elevated TSS, waters experience a reduction in predation from piscivorous fish and birds (Gregory and Levings 1998). In systems with intense predation pressure, this provides a beneficial trade-off (e.g., enhanced survival) to the cost of potential

physical effects (e.g., reduced growth). Turbidity levels of about 23 Nephalometric Turbidity Units (NTU) have been found to minimize bird and fish predation risks (Gregory 1993). Exposure duration is a critical determinant of the occurrence and magnitude of physical or behavioral effects (Newcombe and MacDonald 1991). Salmonids have evolved in systems that periodically experience short-term pulses (days to weeks) of high suspended sediment loads, often associated with flood events, and are adapted to such high pulse exposures. Adult and larger juvenile salmonids appear to be little affected by the high concentrations of suspended sediments that occur during storm and snowmelt runoff episodes (Bjorn and Reiser 1991). However, research indicates that chronic exposure can cause physiological stress responses that can increase maintenance energy and reduce feeding and growth (Redding et al. 1987, Lloyd 1987, Servizi and Martens 1991).

Turbidity, at moderate levels, has the potential to adversely affect primary and secondary productivity, and at high levels, has the potential to injure and kill adult and juvenile fish, and may also interfere with feeding (Spence *et al.* 1996). Newly emerged salmonid fry may be vulnerable to even moderate amounts of turbidity (Bjornn and Reiser 1991). Other behavioral effects on fish, such as gill flaring and feeding changes, have been observed in response to pulses of suspended sediment (Berg and Northcote 1985). Fine redeposited sediments also have the potential to adversely affect primary and secondary productivity (Spence *et al.* 1996), and to reduce incubation success (Bell 1991) and cover for juvenile salmonids (Bjornn and Reiser 1991). There is a low probability of direct mortality, because the turbidity should be localized and brief.

The potential for entrainment of juvenile salmonids will be minimized by using a clamshell bucket for sediment removal. Turbidity will be monitored during dredging and rate of clamshell excavation will be adjusted if needed. Sediment testing will be conducted prior to each annual dredging episode to test for presence of contaminants. Areas tested in 2000 that were contaminated are not proposed for dredging. All decanted water from dredge material will meet Oregon Water Quality Certification criteria prior to discharge into the Columbia River. There will be no loss of riparian vegetation as a result of this project, since none currently exists in the project area. Work will occur within the approved in-water work window of July 1 - October 31 and December 1 - January 31 to reduce the impact of dredging to the vulnerable life stages of salmonids. The potential net effect from of the proposed action is expected to maintain the present conditions within the action area.

1.5.2 Effects on Critical Habitat

NMFS designates critical habitat based on physical and biological features that are essential to the listed species. Essential features for designated critical habitat include substrate, water quality, water quantity, water temperature, food, riparian vegetation, access, water velocity, space and safe passage. Effects on critical habitat from the proposed action are included in the effects description above.

1.5.3 Cumulative Effects

Cumulative effects are defined in 50 CFR 402.02 as those effects of "future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation." Future Federal actions, including the ongoing operation of hydropower systems, hatcheries, fisheries, and land management activities are being (or have been) reviewed through separate section 7 consultation processes. Therefore, these actions are not considered cumulative to the proposed action.

The NMFS is not aware of any specific future non-Federal activities within the action area that would cause greater impacts to listed species than presently occurs. However, development of structures and vegetation clearing along the Willamette and Columbia rivers is likely to continue. The NMFS assumes that future private and state actions will continue at similar intensities as in recent years**.**

1.6 Conclusion

NMFS has determined, based on the available information, that the proposed action covered in this Opinion is not likely to jeopardize the continued existence of listed salmonids or adversely modify critical habitat. NMFS used the best available scientific and commercial data to apply its jeopardy analysis, when analyzing the effects of the proposed action on the biological requirements of the species relative to the environmental baseline, together with cumulative effects. NMFS believes that the proposed action would cause a minor, short-term degradation of anadromous salmonid habitat due to turbidity caused by in-water excavation. Direct mortality is not expected from the use of a clamshell dredge.

1.7 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Conservation recommendations are *discretionary* measures suggested to minimize or avoid adverse effects of a proposed action on listed species, to minimize or avoid adverse modification of critical habitat, or to develop additional information. The NMFS believes the following conservation recommendations are consistent with these obligations, and therefore should be carried out by the Corps:
To monitor the role of ecosystem functions and the extent of these minor modifications, NMFS believes the following conservation recommendation should be carried out by the COE:

1. To the greatest extent possible, the COE should develop a database that consists of all existing permits that have resulted in projects. The database should be compatible with monitoring information that will be produced to meet the requirements of this Opinion. Thus each project entered into the database should be identified by 5th field hydrological unit code (HUC), and contain, where possible, the following information: 1) Permit number; 2) applicant name; 3) project name; 4) the category of activity under which the

permit was issued; 5) location by river mile and lat/long; 5) starting and ending dates for work done under the permit; and 6) the COE contact person.

NMFS believes this information will help to reduce uncertainty about the effects of past and ongoing human and natural factors leading to the status of listed salmon and steelhead, their habitats, and the aquatic ecosystem within the Portland District of the COE.

In order for NMFS to be kept informed of actions minimizing or avoiding adverse effects, or those that benefit listed salmon and steelhead or their habitats, NMFS requests notification of the achievement of any conservation recommendations throught submission of an annual report describing achievements of the permitting process during the previous year.

1.8 Reinitiation of Consultation

This concludes formal consultation on these actions in accordance with 50 CFR 402.14(b)(1). Reinitiation of consultation is required: (1) If the amount or extent of incidental take is exceeded; (2) If the action is modified in a way that causes an effect on the listed species that was not previously considered in the biological assessment and this biological opinion; (3) new information or project monitoring reveals effects of the action that may affect the listed species in a way not previously considered; or (4) a new species is listed or critical habitat is designated that may be affected by the action (50 CFR 402.16).

2. INCIDENTAL TAKE STATEMENT

Section 4 (d) and Section 9 of the ESA prohibit any taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct) of listed species without a specific permit or exemption. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, and sheltering (64 FR 60727; November 8, 1999). Harass is defined as actions that create the likelihood of injuring listed species to such an extent as to significantly alter normal behavior patterns which include, but are not limited to, breeding, feeding, and sheltering. Incidental take is take of listed animal species that results from, but is not the purpose of, the Federal agency or the applicant carrying out an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to, and not intended as part of, the agency action is not considered prohibited taking provided that such taking is in compliance with the terms and conditions of this incidental take statement. An incidental take statement specifies the impact of any incidental taking of threatened species. It also provides reasonable and prudent measures that are necessary to minimize impacts and sets forth terms and conditions with which the action agency must comply in order to implement the reasonable and prudent measures.

2.1 Amount or Extent of the Take

The NMFS anticipates that the action covered by this Opinion has more than a negligible

likelihood of resulting in incidental take of listed salmonids because of detrimental effects from increased turbidity levels (non-lethal), and the potential for direct incidental take during in-water work (lethal and non-lethal). Effects of actions such as the one covered by this Opinion are largely unquantifiable in the short term, and are not expected to be measurable as long term effects on habitat or population levels. Therefore, even though NMFS expects some low level incidental take to occur due to the action covered by this Opinion, the best scientific and commercial data available are not sufficient to enable NMFS to estimate a specific amount of incidental take to the species itself. In instances such as these, the NMFS designates the expected level of take as "unquantifiable." Based on the information provided by the COE and other available information, NMFS anticipates that an unquantifiable amount of incidental take could occur as a result of the action covered by this Opinion. The extent of the take is limited to the project area.

2.2 Reasonable and Prudent Measures

The NMFS believes that the following reasonable and prudent measures are necessary and appropriate to avoid or minimize take of listed salmonid species resulting from the action covered by this Opinion. The COE shall include, as part of the Section 10 River and Harbors Act permit, measures that will:

1. Minimize the amount and extent of incidental take resulting from in-water work required to complete the project addressed in this Opinion by implementing measures to limit the duration and extent of in-water work.

2. Complete a comprehensive monitoring and reporting program to ensure the terms and conditions provided in this Opinion are effective in minimizing the likelihood of take from permitted activities.

2.3 Terms and Conditions

To be exempt from the prohibitions of section 9 of the ESA, the COE must require, as part of the Section 10 Permit, and the applicant and/or their contractors must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are non-discretionary.

1. To implement reasonable and prudent measure #1, above, the COE shall ensure that:

    a. Construction impacts (dredging) will be confined to the minimum area necessary to complete the project.
    b. Turbidity monitoring will be conducted with each dredging event to evaluate the need for modification to the rate of dredging with a clamshell bucket. If turbidity increases more than 10% above background conditions, modification is required and the rate of dredging will be adjusted immediately to return turbidity to background levels.

c. The applicant will conduct sediment analyses at berths prior to each dredging episode to test for presence of contaminants. The sediment characterization from the proposed dredge prism will meet screening criteria for unconfined, open-water disposal or dredging shall not proceed.

d. All in-water work will occur during the approved in-water work period of July 1-October 31 and December 1 - January 31. Extensions of the in-water work period must be approved by a NMFS biologist.

e. Only the rehandle facility shall be used for disposal of dredged material.

2. To implement reasonable and prudent measure #2, above, the COE shall ensure that:

a. Within 30 days of completing a dredging episode, the COE will submit a monitoring report to NMFS describing the COE's success meeting these terms and conditions. This report will consist of the following information.

i. Project identification.

(1) Project name;

(2) starting and ending dates of work completed for this project; and

(3) the name and address of the construction supervisor.

ii. A narrative assessment of the project's effects on natural stream function.

iii. Photographic documentation of environmental conditions at the project site before, during and after project completion.

(1) Photographs will include general project location views and close-ups showing details of the project area and project, including pre and post construction.

(2) Each photograph will be labeled with the date, time, photo point, project name, the name of the photographer, and a comment describing the photograph's subject.

(3) Relevant habitat conditions include characteristics of channels, streambanks, riparian vegetation, flows, water quality, and other visually discernable environmental conditions at the project area, and upstream and downstream of the project.

b. Prior to the dredging activity at this project location, the applicant will conduct a sediment analysis at each site considered for dredging and submit results to NMFS for review to ensure that sediment has been sampled for presence of contaminants.

c. If a dead, injured, or sick endangered or threatened species specimen is located, initial notification must be made to the National Marine Fishery Service Law Enforcement Office, located at Vancouver Field Office, 600 Maritime, Suite 130, Vancouver, Washington 98661; telephone: 360/418-4246. Care should be taken in handling sick or injured specimens to ensure effective treatment and care or the handling of dead specimens to preserve biological material in the best possible state for later analysis of cause of death. In conjunction with the care of sick or

injured endangered and threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to carry out instructions provided by Law Enforcement to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed.

d. Monitoring reports will be submitted to:

National Marine Fisheries Service
Attn: OSB2001-0230-FEC
525 NE Oregon Street
Portland, OR 97232

3. MAGNUSON-STEVENS ACT

3.1 Background

The objective of the Essential Fish Habitat (EFH) consultation is to determine whether the proposed action may adversely affect designated EFH for relevant species, and to recommend conservation measures to avoid, minimize, or otherwise offset potential adverse effects to EFH resulting from the proposed action.

3.2 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-297), requires the inclusion of EFH descriptions in Federal fishery management plans. In addition, the MSA requires Federal agencies to consult with NMFS on activities that may adversely affect EFH.

EFH means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (MSA §3). For the purpose of interpreting the definition of essential fish habitat: Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species' full life cycle (50CFR600.110).

Section 305(b) of the MSA (16 U.S.C. 1855(b)) requires that:

- Federal agencies must consult with NMFS on all actions, or proposed actions, authorized, funded, or undertaken by the agency, that may adversely affect EFH;

- NMFS shall provide conservation recommendations for any Federal or State activity that may adversely affect EFH;
- Federal agencies shall within 30 days after receiving conservation recommendations from NMFS provide a detailed response in writing to NMFS regarding the conservation recommendations. The response shall include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations of NMFS, the Federal agency shall explain its reasons for not following the recommendations.

The MSA requires consultation for all actions that may adversely affect EFH, and does not distinguish between actions within EFH and actions outside EFH. Any reasonable attempt to encourage the conservation of EFH must take into account actions that occur outside EFH, such as upstream and upslope activities, that may have an adverse effect on EFH. Therefore, EFH consultation with NMFS is required by Federal agencies undertaking, permitting or funding activities that may adversely affect EFH, regardless of its location.

3.3 Identification of EFH

The Pacific Fisheries Management Council (PFMC) has designated EFH for federally-managed fisheries within the waters of Washington, Oregon, and California. The designated EFH for groundfish and coastal pelagic species encompasses all waters from the mean high water line, and upriver extent of saltwater intrusion in river mouths, along the coasts of Washington, Oregon and California, seaward to the boundary of the U.S. exclusive economic zone (370.4 km)(PFMC 1998a, 1998b). Freshwater EFH for Pacific salmon includes all those streams, lakes, ponds, wetlands, and other water bodies currently, or historically accessible to salmon in Washington, Oregon, Idaho, and California, except areas upstream of certain impassable man-made barriers (as identified by the PFMC), and longstanding, naturally-impassable barriers (i.e., natural waterfalls in existence for several hundred years)(PFMC 1999). In estuarine and marine areas, designated salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (370.4 km) offshore of Washington, Oregon, and California north of Point Conception to the Canadian border.

Detailed descriptions and identifications of EFH for the groundfish species are found in the Final Environmental Assessment/Regulatory Impact Review for Amendment 11 to The Pacific Coast Groundfish Management Plan (PFMC 1998a) and the NMFS Essential Fish Habitat for West Coast Groundfish Appendix (Casillas *et al.* 1998). Detailed descriptions and identifications of EFH for the coastal pelagic species are found in Amendment 8 to the Coastal Pelagic Species Fishery Management Plan (PFMC 1998b). Detailed descriptions and identifications of EFH for salmon are found in Appendix A to Amendment 14 to the Pacific Coast Salmon Plan (PFMC 1999). Assessment of the potential adverse effects to these species' EFH from the proposed action is based on this information.

3.4 Proposed Actions

The proposed actions are detailed above in section 1.2. The action area includes designated critical habitat affected by the proposed action within the Willamette River for dredging and Columbia River for the rehandle site. This area has been designated as EFH for various life stages of chinook and coho salmon and starry flounder (*Platyichthys stellatus*).

3.5 Effects of Proposed Action

As described in detail in section 1.5, the proposed activities may result in detrimental short- and long-term adverse effects to a variety of habitat parameters. Excavation of river bottom material will result in disturbance of the substrate and a temporary increase in turbidity.

3.6 Conclusion

NMFS believes that the proposed action may adversely affect the EFH for Pacific salmon species and Starry flounder (*Platyichthys stellatus*).

3.7 EFH Conservation Recommendations

Pursuant to section 305(b)(4)(A) of the Magnuson-Stevens Act, NMFS is required to provide EFH conservation recommendations for any Federal or state agency action that would adversely affect EFH. The conservation measures proposed for the project by the Corps, all Conservation Recommendations outlined above in Section 1.7 and all of the Reasonable and Prudent Measures and the Terms and Conditions contained in Sections 2.2 and 2.3 are applicable to EFH. Therefore, NMFS incorporates each of those measures here as EFH conservation recommendations.

3.8 Statutory Response Requirement

Please note that the Magnuson-Stevens Act (section 305(b)) and 50 CFR 600.920(j) requires the Federal agency to provide a written response to NMFS after receiving EFH conservation recommendations within 30 days of its receipt of this letter. This response must include a description of measures proposed by the agency to avoid, minimize, mitigate or offset the adverse impacts of the activity on EFH. If the response is inconsistent with a conservation recommendation from NMFS, the agency must explain its reasons for not following the recommendation.

3.9 Consultation Renewal

The Corps must reinitiate EFH consultation with NMFS if either action is substantially revised or new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920).

4. LITERATURE CITED

Armstrong, D.A., B.G. Stevens, and J.C. Hoeman. 1982. Distribution and abundance of Dungeness crab and *Crangon* shrimp, and dredged-related mortality of invertebrates and fish in Grays Harbor, Washington. Tech. Rpt. School of Fisheries. Univ. of Washington, Washington Department of Fisheries, and Seattle District Corps of Engineers. 349 p.

Bell, M.C. 1991. Fisheries handbook of Engineering requirements and biological criteria. Fish Passage Development and Evaluation Program. U.S. Army Corps of Engineers. North Pacific Division.

Berg, L. and T.G. Northcote. 1985. "Changes In Territorial, Gill-Flaring, and Feeding Behavior in Juvenile Coho Salmon (Oncorhynchus kisutch) Following Short-Term Pulses of Suspended Sediment." Canadian Journal of Fisheries and Aquatic Sciences 42: 1410-1417.

Birtwell, I. K., G. F. Hartman, B. Anderson, D. J. McLeay, and J. G. Malick. 1984. "A Brief Investigation of Arctic Grayling (Thymallus arcticus) and Aquatic Invertebrates in the Minto Creek Drainage, Mayo, Yukon Territory: An Area Subjected to Placer Mining." Canadian Technical Report of Fisheries and Aquatic Sciences 1287.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19:83-138.

Boyd, F.C. 1975. Fraser River dredging guide. Tech. Rpt. Series No. PAC/T-75-2. Fisheries and Marine Service, Environment Canada.

Burgner, R.L. 1991. Life history of sockeye salmon (*Oncorhynchus nerka*). Pages 1-117 *In:* Groot, C. and L. Margolis (eds.). 1991. Pacific salmon life histories. Vancouver, British Columbia: University of British Columbia Press.

Busby, P., S. Grabowski, R. Iwamoto, C. Mahnken, G. Matthews, M. Schiewe, T. Wainwright, R. Waples, J. Williams, C. Wingert, and R. Reisenbichler. 1995. Review of the status of steelhead (*Oncorhynchus mykiss*) from Washington, Idaho, Oregon, and California under the U.S. Endangered Species Act. 102 p. plus 3 appendices.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-27, 261p.

Casillas, E., L. Crockett, Y. deReynier, J. Glock, M. Helvey, B. Meyer, C. Schmitt, M. Yoklavich, A. Bailey, B. Chao, B. Johnson, and T. Pepperell,. 1988. Essential Fish Habitat West Coast Groundfish Appendix. National Marine Fisheries Service. Seattle, Washington. 778 p.

City of Portland, Bureau of Environmental Services. Website accessed October 2001 http://www.cleanrivers-pdx.org/clean_rivers/ws_willamette.htm

DeVore, P. W., L. T. Brooke, and W. A. Swenson. 1980. "The Effects of Red Clay Turbidity and Sedimentation on Aquatic Life In the Nemadji River System. Impact of Nonpoint Pollution Control on Western Lake Superior." S. C. Andrews, R. G. Christensen, and C. D. Wilson. Washington, D.C., U.S. Environmental Protection Agency. EPA Report 905/9-79-002-B.

Dutta, L.K. and P. Sookachoff. 1975a. Assessing the impact of a 24" suction pipeline dredge on chum salmon fry in the Fraser River. Fish. And Marine Serv., Environment Canada, Tech. Rep. Ser. No. PAC/T-75-26. 24 p.

Emmet, R.L., G.T. McCabe, Jr. and W.D. Muir. 1988. Effects of the 1980 Mount St. Helens eruption on Columbia River estuarine fishes: implications for dredging on Northwest estuaries. Pages 74-91 *In:* C. A. Simenstad (ed.) Effects of dredging on anadromous Pacific coast fishes. Washington Sea Grant Program. Washington State University. Seattle, Washington.

Gregory, R. S., and C. D. Levings. 1998. "Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon." Transactions of the American Fisheries Society 127: 275-285.

Gregory, R.S. 1993. Effect of turbidity on the predator avoidance behavior of juvenile chinook salmon (Oncorhynchus tshawytcha). Canadian J. Fish. Aquatic Sciences 50:241-246.

Gregory, R. S. 1988. Effects of Turbidity on benthic foraging and predation risk in juvenile chinook salmon. Pages 64-73 *In:* C. A. Simenstad (ed.) Effects of dredging on anadromous Pacific coast fishes. Washington Sea Grant Program. Washington State University. Seattle, Washington.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-393 *In:* Groot, C. and L. Margolis (eds.). 1991. Pacific salmon life histories. Vancouver, British Columbia: University of British Columbia Press.

Johnson, O.W., W.S. Grant, R.G. Cope, K. Neely, F.W. Waknitz, and R.S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-32, 280 p.

Kirn, R.A., R.D. Ledgerwood and A.L. Jensen. 1986. Diet of subyearling chinook salmon (*Oncorhynchus tshawytscha*) in the Columbia River estuary and changes effected by the 1980 eruption of Mount St. Helens. Northwest Science 60:191-195.

Lloyd, D. S. 1987. Turbidity as a Water Quality Standard for Salmonid Habitats in Alaska. North American Journal of Fisheries Management 7:34-45.

Lloyd, D. S., J. P. Koenings, and J. D. LaPerriere. 1987. "Effects of Turbidity in Fresh Waters of Alaska." North American Journal of Fisheries Management 7: 18-33.

Matthews, G.M. and R.S. Waples. 1991. Status review for Snake River spring and summer chinook salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NWC-200, 75 p.

McLeay, D. J., G. L. Ennis, I. K. Birtwell, and G. F. Hartman. 1984. "Effects On Arctic Grayling (Thymallus arcticus) of Prolonged Exposure to Yukon Placer Mining Sediment: A Laboratory Study." Canadian Technical Report of Fisheries and Aquatic Sciences 1241.

McLeay, D. J., I. K. Birtwell, G. F. Hartman, and G. L. Ennis. 1987. "Responses of Arctic Grayling (Thymallus arcticus) To Acute and Prolonged Exposure to Yukon Placer Mining Sediment." Canadian Journal of Fisheries and Aquatic Sciences 44: 658-673.

Morton, J.W. 1977. Ecological effects of dredging and dredge spoil disposal: a literature review. U.S. Fish and Wildlife Service Technical Paper No. 94. 33 p.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

Newcombe, C. P., and D. D. MacDonald. 1991. "Effects of Suspended Sediments on Aquatic Ecosystems." North American Journal of Fisheries Management 11: 72-82.

PFMC (Pacific Fishery Management Council), 1998a. Final Environmental Assessment/Regulatory Review for Amendment 11 to the Pacific Coast Groundfish Fishery Management Plan. October 1998.

NMFS. 2000. Biological Opinion: Reinitiation of Consultation on Operation of the Federal Columbia River Power System, Including the Juvenile Fish Transportation Program, and

19 Bureau of Reclamation Projects in the Columbia Basin. Web site: http://www.nwr.noaa.gov/1hydrop/hydroweb/fedrec.htm

PFMC (Pacific Fishery Management Council), 1998b. The Coastal Pelagic Species Fishery Management Plan: Amendment 8. Portland, Oregon.

PFMC (Pacific Fishery Management Council). 1999. Amendment 14 to the Pacific Coast Salmon Plan. Appendix A: Description and Identification of Essential Fish Habitat, Adverse Impacts and Recommended Conservation Measures for Salmon. Portland, Oregon.

Redding, J. M., C. B. Schreck, and F. H. Everest. 1987. "Physiological Effects on Coho Salmon and Steelhead of Exposure to Suspended Solids." Transactions of the American Fisheries Society 116: 737-744.

Salo, E.O. 1991. Life history of chum salmon (*Oncorhynchus keta*). Pages 231-309 *In:* Groot, C. and L. Margolis (eds.). 1991. Pacific salmon life histories. Vancouver, British Columbia: University of British Columbia Press.

Scannell, P.O. 1988. Effects of Elevated Sediment Levels from Placer Mining on Survival and Behavior of Immature Arctic Grayling. Alaska Cooperative Fishery Unit, University of Alaska. Unit Contribution 27.

Servizi, J.A. 1988. Sublethal effects of dredged sediments on juvenile salmon. Pages 57-63 *In:* C. A. Simenstad (ed.) Effects of dredging on anadromous Pacific coast fishes. Washington Sea Grant Program. Washington State University. Seattle, Washington

Servizi, J. A., and Martens, D. W. 1991. "Effects of Temperature, Season, and Fish Size on Acute Lethality of Suspended Sediments to Coho Salmon". Canadian Journal of Fisheries and Aquatic Sciences 49:1389-1395.

Sigler, J.W. 1988. Effects of chronic turbidity on anadromous salmonids: recent studies and assessment techniques perspective. Pages 26-37 *In:* C. A. Simenstad (ed.) Effects of dredging on anadromous Pacific coast fishes. Washington Sea Grant Program. Washington State University. Seattle, Washington.

Sigler, J. W., T. C. Bjornn, and F. H. Everest. 1984. "Effects of Chronic Turbidity on Density and Growth of Steelheads and Coho Salmon." Transactions of the American Fisheries Society 113: 142-150. 1984.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. ManTech Environmental Research Services, Inc., Corvallis, Oregon, to National Marine Fisheries Service, Habitat Conservation Division, Portland, Oregon (Project TR-4501-96-6057).

Tutty, B. D. 1976. Assessment of techniques used to quantify salmon smolt entrainment by a hydraulic suction hopper dredge in the Fraser River estuary. Fish. And Mar. serv. Environment Canada. Tech. Rept. Ser. No. PAC/T-76-16.

Waples, R.S., O.W. Johnson, and R.P. Jones, Jr. 1991a. Status review for Snake River sockeye salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-195. 23 p.

Waples, R.S., R.P. Jones, Jr., B.R. Beckman, and G.A. Swan. 1991b. Status review for Snake River fall chinook salmon. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-201. 73 p.

Whitman, R.P., T.P. Quinn and E.L. Brannon. 1982. Influence of suspended volcanic ash on homing behavior of adult chinook salmon. Trans. Am. Fish. Soc. 113:142-150.

Willamette Restoration Initiative (WRI). 1999. Restoring the Willamette Basin: Issues and Challenges. Prepared by Institute for the Northwest. Report accessed at: http://www.oregonwri.org/basin_restore/rest_will_basin2a.pdf